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A retrieval analysis perspective on revision for infection

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ABSTRACT

Background: Retrieval analysis has long served the orthopaedic community as a tool for understanding implant failure modes; however, what retrieval studies can reveal about the nature of prosthetic joint infection (PJI) remains unknown. We hypothesize that records from a comprehensive joint retrieval program should corroborate clinically-reported temporal characteristics of prosthesis-related infection.
Methods: We examined 2527 records documenting a decade of explanted hip and knee components to quantify the following: (1) the relative contribution of infection to revision arthroplasty; (2) the effects of joint type, revision status, and reason for retrieval on indwelling time; and (3) whether the temporal distribution of infected explants reflects clinical experience.
Results: In this series, 20% (507/2527) of explants were performed for infection, with PJI being more commonly implicated in the retrieval of revision implants than of primaries. Infected prostheses were explanted 23.2 months sooner on average than those retrieved for other causes. Within the subset of infected devices, revision components were explanted 11.2 months sooner than primaries, with no appreciable difference observed between hips and knees. Retrieval-based temporal distributions were most similar to PJI studies with endpoint enrollment or long duration follow-up, suggesting a later average onset of infection than reported in comparable clinical studies with short (<10-year) follow-up.
Conclusions: Infection represents a major cause of revision arthroplasty, and is associated with shorter indwelling times in revision components than in primaries. Studies with less than 10 years of follow-up are likely to under-report late PJI.

Introduction

Recent studies have shown that the overall incidence of prosthetic joint infection (PJI) remains constant at 1%-2% despite decades-long efforts by the medical and surgical communities to improve all aspects of prevention, diagnosis, and treatment [1,2]. Of primary concern are relatively high mortality rates that suggest a poorer prognosis for PJI patients than for those diagnosed with either prostate or breast cancer [1]. The rarity of infection in total joint arthroplasty makes this a difficult disease to study. As a result, much of the epidemiological research on PJI is underpowered [3-5], and wide variation exists among reports of PJI incidence, its contribution to revision arthroplasty, and the degree to which infection risk changes over time after the index procedure.

In the present work, we sought to determine whether monitoring explanted hip and knee arthroplasty components at multiple institutions could provide further insight into the epidemiological characteristics of PJI. Our primary objectives were to assess the following: (1) the proportion of retrieved prosthetic hip and knee devices explanted due to infection; (2) the temporal distribution of infected retrievals with respect to index arthroplasty; and (3) whether the temporal distributions of infected explants from a comprehensive, multi-center retrieval study are appropriately representative of the clinical experience. Although retrieval analysis alone is fundamentally incapable of painting a complete picture of the

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epidemiology of PJI, it may have implications for both the design and interpretation of longitudinal studies when taken together with clinical research.

Material and methods

Based on the inclusion/exclusion criteria detailed in Figure 1, we selected 2527 records from our retrieval database cataloging hip and knee prostheses explanted between June 1, 2007 and May 31, 2017. In an effort to minimize selection bias, each included device was retrieved at one of 2 tertiary care referral centers (henceforth identified as "Institution A" and "Institution B") that, by agreement, contributed all available explants to our retrieval laboratory during the study period. Explant collection and analysis was performed in accordance with procedures approved by local institutional review boards at each center.

Within this cohort of hip and knee components, 62% (1561) were explanted at Institution A and 38% (966) at Institution B. Records contained sufficient information to statistically examine relationships between component indwelling time and 3 factors: joint type (categories: hip, knee), "ordinality" (categories: primary, revision), and surgeon-reported reason for retrieval (categories: infection, all other causes). All analyses were performed in R (version 3.4.4; R Foundation, Vienna, Austria) using RStudio (version 1.1.453; RStudio, Inc., Boston, MA), and hypothesis test results were considered statistically significant at the $\alpha = 0.05$ level. A more detailed explanation of the statistical methods used in this analysis is available as an online supplement.

Contribution of infection to revision arthroplasty

The proportion of retrievals associated with infection was computed by simple division (ie, number of infections over total number of records) for the overall dataset, as well as for relevant subsets.

Temporal distribution of retrievals for infection

Two-way analysis of variance was performed as a coarse indicator of whether the joint type and/or ordinality factors are associated with significant variations in indwelling time. Since these distributions exhibit considerable right skew, more detailed analyses were performed using non-parametric methods. Each individual distribution was characterized in terms of its median and associated 95% confidence interval following Altman et al [6]; likewise, the median difference (ie, the median of all possible differences, a measure that is more statistically rigorous than the simple difference of medians) and associated CI were computed for certain pairs of distributions. Numerous hypothesis tests are available to detect specific differences between distributions; here we employed a modified median test (using Fisher's exact method) and the Mann-Whitney *U*-test to evaluate differences in location, as well as the Kolmogorov-Smirnov test to identify shape disparities.

Comparison to published reports of PJI timing

We identified 5 relevant studies in the orthopaedic literature detailing the temporal distribution of PJI in hips and knees combined [5,7-10], 2 reporting the same in hips alone [11,12], and 6 in knees alone [4,13-17]. To facilitate comparison, retrieval indwelling times were segmented into histogram bins directly mirroring the structure of each literature report. Each pair of binned distributions was analyzed qualitatively by overlaying the normalized histograms, and quantitatively using the chi-squared test for independence, whose test statistic provides a rough measure of evidence that the distributions differ.

Results

Contribution of infection to revision arthroplasty

Infection accounts for 20% (507/2527) of the combined retrievals from Institutions A and B. Table 1 presents a summary of these data broken down by ordinality, joint type, and institution. Note that infection is more commonly reported as the reason for retrieval of revision implants than of primary implants.

Temporal distribution of retrievals for infection

As illustrated in Table 2 and Figure 2, the median infected explant occurred after 18.5 months (95% CI 17.0-21.4), and the median aseptic explant after 50.5 months (95% CI 47.1-53.2). The median difference shows that components explanted due to infection were retrieved 23.2 months (95% CI 19.4-27.2) sooner on average than components explanted for all other causes combined (Table 3).

Analysis of variance run on the entire set of included records (Table 4) identified significant effects associated with ordinality and joint type, but not the interaction between these 2 factors. Within the subset of devices explanted for infection, only ordinality was significant.

More detailed comparisons of individual distributions within the full set of records (Table 3) identified a tendency for knees to fail (for any reason, including infection) sooner than hips by an average of 5.6 months (95% CI 2.1-9.4). The median knee was explanted after 38.6 months (95% CI 36.4-41.9), and the median hip after 51.5 months (95% CI 47.1-55.8) (Table 2). This relationship was also associated with a significant ($P < .0001$) median test; however, results were not consistently significant when the hip vs knee comparison was restricted to only revision components. Within the infected subset, knee and hip prostheses exhibited similar indwelling times. The median septic knee was explanted after 19.7 months (95% CI 17.6-23.8), and the median septic hip after 17.0 months (95% CI 13.4-20.7) (Table 2). The median difference of 2.7 months (95% CI −0.4 to 6.2) was not significant (Table 3).

Revision arthroplasties failed (for any reason, including infection) sooner than primaries by an average of 17.1 months (95% CI 13.9-20.7) (Table 3). The median revision component was explanted after 27.5 months (95% CI 25.3-30.1), and the median primary component after 52.9 months (95% CI 49.3-55.3) (Table 2). Within the infected subset, revision arthroplasties failed sooner than primaries by an average of 11.2 months (95% CI 7.0-15.6) (Table 3). The median septic revision component was explanted after 12.2 months (95% CI 10.5-15.3), and the median septic primary component after 25.7 months (95% CI 21.7-31.5) (Table 2).

Indwelling time distributions for infected retrievals are shown in Figure 3 as approximate, kernel-smoothed densities and as empirical cumulative distributions.

Comparison to published reports of PJI timing

The comparative histograms derived by binning raw retrieval indwelling times to mirror relevant clinical studies are illustrated in Figure 4 and detailed in Table 5. Retrieval distributions most strongly reflect the results of studies most similar in design to the retrieval process (ie, those that either enrolled subjects at the time of revision for PJI or those in which maximum follow-up was at least a decade). These similarities are visually apparent in the cases of Schroer et al [13] and Lai et al [7], both of which used endpoint enrollment, as well

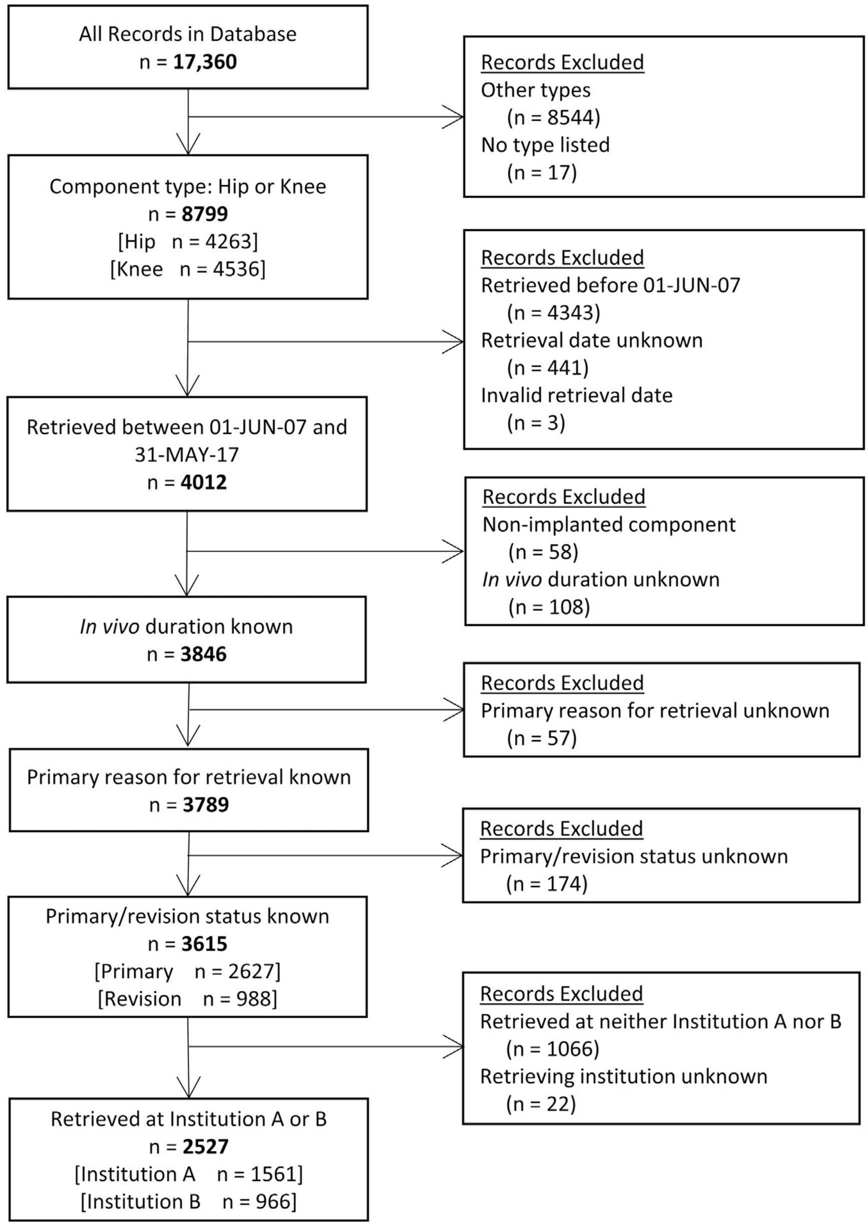

Figure 1. Record inclusion/exclusion produced a dataset detailing 2527 devices retrieved at either of 2 institutions for which our laboratory served as the principal explant recipient during the study period.

as in Berbari et al [5] and Vessely et al [14], both of which followed patients for extended durations. Significant chi-squared tests associated with visually similar distributions are not particularly surprising, especially in the case of the comparison to Berbari et al, as large sample sizes lead to detection of small distributional differences that may have little clinical relevance. On the other hand, retrieval distributions suggest a much higher density of late PJI than do studies like Grammatico-Guillon et al [9] and Pulido et al [8], in which patients were enrolled based on the date of the index procedure and followed for relatively short periods of time (maximum of 40 and 76 months, respectively). The chi-squared comparisons performed against these distributions produced much larger values of the test statistic, indicating that there is strong evidence of a difference in distributions.

Table 1
Proportion of retrieved devices explanted due to infection, grouped by retrieving institution.

Explant type	Records from Institutions A and B			Records from Institution A			Records from Institution B		
	Primary	Revision	Primary or revision	Primary	Revision	Primary or revision	Primary	Revision	Primary or revision
Hip	15% (104/688)	21% (70/330)	17% (174/1018)	13% (62/466)	21% (44/211)	16% (106/677)	19% (42/222)	22% (26/119)	20% (68/341)
Knee	18% (177/999)	31% (156/510)	22% (333/1509)	21% (136/636)	40% (99/248)	27% (235/884)	11% (41/363)	22% (57/262)	16% (98/625)
Hip or knee	17% (281/1687)	27% (226/840)	20% (507/2527)	18% (198/1102)	31% (143/459)	22% (341/1561)	14% (83/585)	22% (83/381)	17% (166/966)

Table 2
Analysis of indwelling duration for explants retrieved for any reason (including infection), those retrieved specifically due to infection, and those retrieved for all reasons other than infection.

Explant type	Retrieved for any reason			Retrieved for infection			Retrieved for all other causes		
	Primary	Revision	Primary or revision	Primary	Revision	Primary or revision	Primary	Revision	Primary or revision
Hip	59.0 (54.4-63.7) n = 688	28.2 (22.6-36.4) n = 330	51.5 (47.1-55.8) n = 1018	21.4 (17.0-27.1) n = 104	11.6 (4.9-16.1) n = 70	17.0 (13.4-20.7) n = 174	64.5 (59.8-70.9) n = 584	37.8 (29.4-49.2) n = 260	59.2 (55.0-62.8) n = 844
Knee	46.5 (42.7-51.4) n = 999	27.2 (24.9-30.1) n = 510	38.6 (36.4-41.9) n = 1509	30.2 (23.9-38.2) n = 177	13.3 (10.7-17.1) n = 156	19.7 (17.6-23.8) n = 333	51.0 (46.0-55.0) n = 822	35.5 (31.1-40.5) n = 354	44.4 (42.0-47.1) n = 1176
Hip or knee	52.9 (49.3-55.3) n = 1687	27.5 (25.3-30.1) n = 840	42.9 (40.2-45.1) n = 2527	25.7 (21.7-31.5) n = 281	12.2 (10.5-15.3) n = 226	18.5 (17.0-21.4) n = 507	57.2 (53.7-60.1) n = 1406	36.1 (31.9-40.4) n = 614	50.5 (47.1-53.2) n = 2020

Median time to explant is specified in months, and listed with the associated 95% CI and number of applicable records.

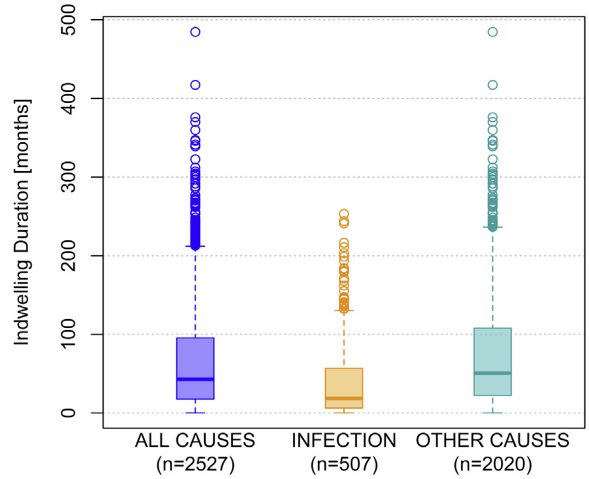

Figure 2. A box and whiskers plot showing quartiles of the indwelling time distributions for all retrievals, as well as for the septic and aseptic subsets. Devices explanted due to infection exhibit a clear tendency toward earlier revision when compared to devices explanted for all other causes combined.

Discussion

Given that modern total hip and total knee replacement procedures were first performed in the United States within the last half century (in 1969 and 1971, respectively [18-20]) and that the average patient presenting for primary arthroplasty is approximately 60 years old [21], researchers have only recently begun to paint a clear picture of the long-term survivorship and failure modes of these interventions. Myriad factors confound extended, longitudinal study of implant failures including the relatively rapid evolution of implant design, introduction of new biomaterials, and shifting patient demographics. As noted by Vessely et al [14], many of the complications observed in the early days of total hip arthroplasty and total knee arthroplasty have now been addressed, leaving infection as a more prominent cause of failure in modern joint replacement.

Results from the present study suggest that approximately 20% of combined hip and knee revision arthroplasties are performed for the purpose of treating PJI. Literature reports are abundant for revision of primary knees, and suggest that 15% [22] to 33% [23] of these procedures are infection related [13,14,22-26]. In this study, 18% (177/999) of primary knee explant records cited infection as the reason for retrieval. We also observed that PJI accounted for a larger fraction of explanted revision components, which is again consistent with the clinical literature [4,13,14,22-31].

Several authors note that infection is a more prominent cause of revision within the first several years after primary total knee arthroplasty than it is after longer indwelling periods [13,23,25,26,30]. Schroer et al [13] found that 23% (68/298) of primary knees explanted within 2 years were infected vs 13% (69/546) of those explanted after more than 2 years. Sharkey et al [26] observed somewhat higher proportions (38% within 2 years, and 22% subsequently) during a similar, single-center study that analyzed 781 re-operations of primary knee arthroplasties over a 10-year period. Our retrieval series also suggests that infection accounts for a higher proportion of revisions during early follow-up, with PJI linked to 27% (77/286) of knees explanted within 2 years after primary arthroplasty, and just 14% (100/713) of those explanted beyond 2 years. Although consistency with the clinical literature is unsurprising, it is nevertheless an important observation that must be disseminated to maintain the relevance of retrieval programs.

Table 3
Statistical comparisons of the temporal distributions of explants based on joint type (hip vs knee), ordinality (primary vs revision), and reason for retrieval (infection vs all other causes combined).

Comparison	Median difference (months)	Median test	Mann-Whitney *U*-test		Kolmogorov-Smirnov test	
	Δ (95% CI)	*P* value	*U*	*P* value	*D*	*P* value
Infection vs other causes						
Infection vs other causes	−23.2 (**−27.2 to −19.4**)	**<.0001**	310,291	**<.0001**	0.305	**<.0001**
Hip vs knee, all causes						
All hip vs all knee	5.6 (**2.1 to 9.4**)	**<.0001**	826,918	**.0011**	0.104	**<.0001**
Primary hip vs primary knee	6.9 (**2.1 to 11.9**)	**.0015**	371,668	**.0044**	0.098	**.0008**
Revision hip vs revision knee	2.0 (−1.7 to 6.6)	.94	87,717	.30	0.164	**<.0001**
Hip vs knee, infection only						
Infected hip vs infected knee	−2.7 (−6.2 to 0.4)	.16	26,309	.089	0.125	.056
Infected primary hip vs infected primary knee	−5.6 (−12.9 to 0.3)	.11	7990	.065	0.133	.20
Infected revision hip vs infected revision knee	−2.0 (−5.5 to 1.1)	.67	4884	.21	0.198	**.046**
Primary vs revision, all causes						
All primary vs all revision	17.1 (**13.9 to 20.7**)	**<.0001**	896,780	**<.0001**	0.195	**<.0001**
Primary hip vs revision hip	18.4 (**11.8 to 25.0**)	**<.0001**	139,841	**<.0001**	0.227	**<.0001**
Primary knee vs revision knee	16.0 (**12.4 to 20.1**)	**<.0001**	327,176	**<.0001**	0.199	**<.0001**
Primary vs revision, infection only						
Infected primary vs infected revision	11.2 (**7.0 to 15.6**)	**<.0001**	41,304	**<.0001**	0.247	**<.0001**
Infected primary hip vs infected revision hip	8.3 (**1.9 to 15.4**)	**.0089**	4564	**.0046**	0.238	**.017**
Infected primary knee vs infected revision knee	13.3 (**8.1 to 19.6**)	**<.0001**	18,523	**<.0001**	0.269	**<.0001**

Hypothesis test results printed in bold are considered significant at the $\alpha = 0.05$ level.
Due to the diverse nature of the dataset and driving research questions, 3 different statistical tests are relevant to the analysis. Most, but not all, show concordance in assigning significance.

Table 4
Two-way analysis of variance results illustrating the relative indwelling time contribution of 2 factors: ordinality (categories: primary, revision) and joint type (categories: hip, knee).

Factor	Explants for all causes		Explants for infection	
	F	*P* value	*F*	*P* value
Ordinality	$F_{1,2523} = 87.04$	**$<2 \times 10^{-16}$**	$F_{1,503} = 33.07$	**1.55×10^{-8}**
Joint type	$F_{1,2523} = 38.59$	**6.09×10^{-10}**	$F_{1,503} = 0.34$	.56
Interaction	$F_{1,2523} = 0.80$	.37	$F_{1,503} = 0.81$	.37

Hypothesis test results printed in bold are considered significant at the $\alpha = 0.05$ level.

The kernel-smoothed estimates and empirical cumulative distributions in Figure 3 provide visual confirmation of the results obtained by statistical testing, namely that infected hip and infected knee prostheses are retrieved after similar indwelling periods, and that infected revision devices are generally explanted sooner than infected primaries. Furthermore, these retrieval data suggest that studies with short follow-up are likely to under-report late infections, particularly for primary implants in which more than 10% of revisions may be performed after at least 10 years in vivo.

Determining whether retrievals for PJI corroborate the clinical experience is complicated by the wide variety of study designs and reporting formats followed in the literature [4,5,7-17]. We therefore compared temporal data from retrievals to the literature on a study-by-study basis, ensuring pairwise consistency in histogram binning. Retrieval results were more consistent with some studies than others, suggesting that cohort definition (ie, basing cohorts on the date of index arthroplasty vs the date of PJI diagnosis/treatment) is particularly important and should be considered when interpreting the results of longitudinal infection studies.

Observing PJI from the perspective of retrieved implants is advantageous in that a study of fixed duration can capture infections occurring after significantly longer periods of effective follow-up; for example, indwelling durations prior to revision for infection

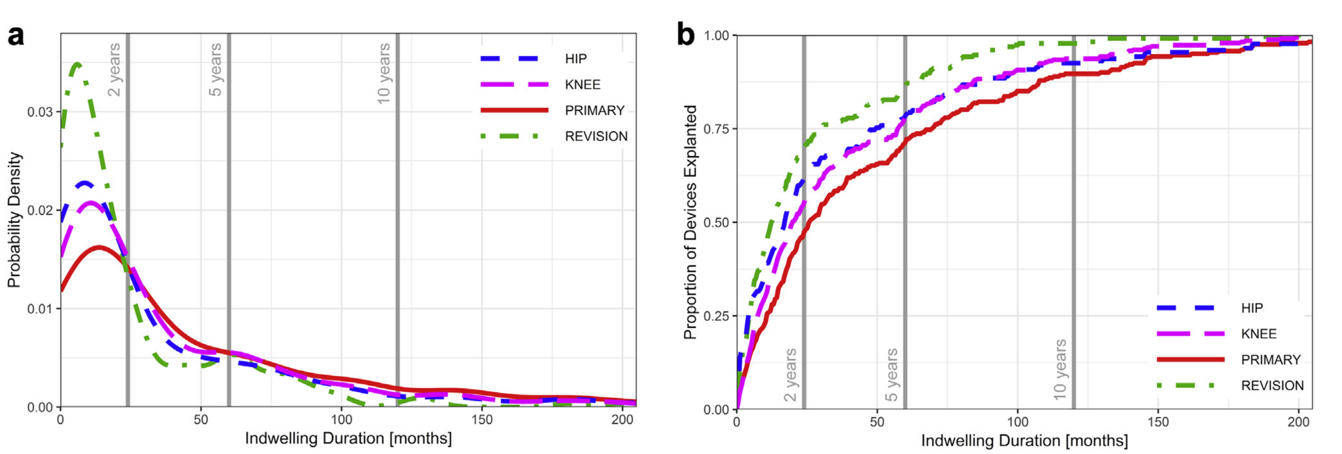

Figure 3. Distribution of indwelling durations associated with devices explanted for infection among included records from Institutions A and B, shown as Gaussian kernel-smoothed densities (a) and also as empirical cumulative distributions (b). The area below any one probability density function between 2 distinct temporal bounds can be interpreted as the expected conditional probability of a device of the respective category (ie, hip, knee, primary, or revision) having been explanted during the selected time period, given that the device was retrieved due to infection.

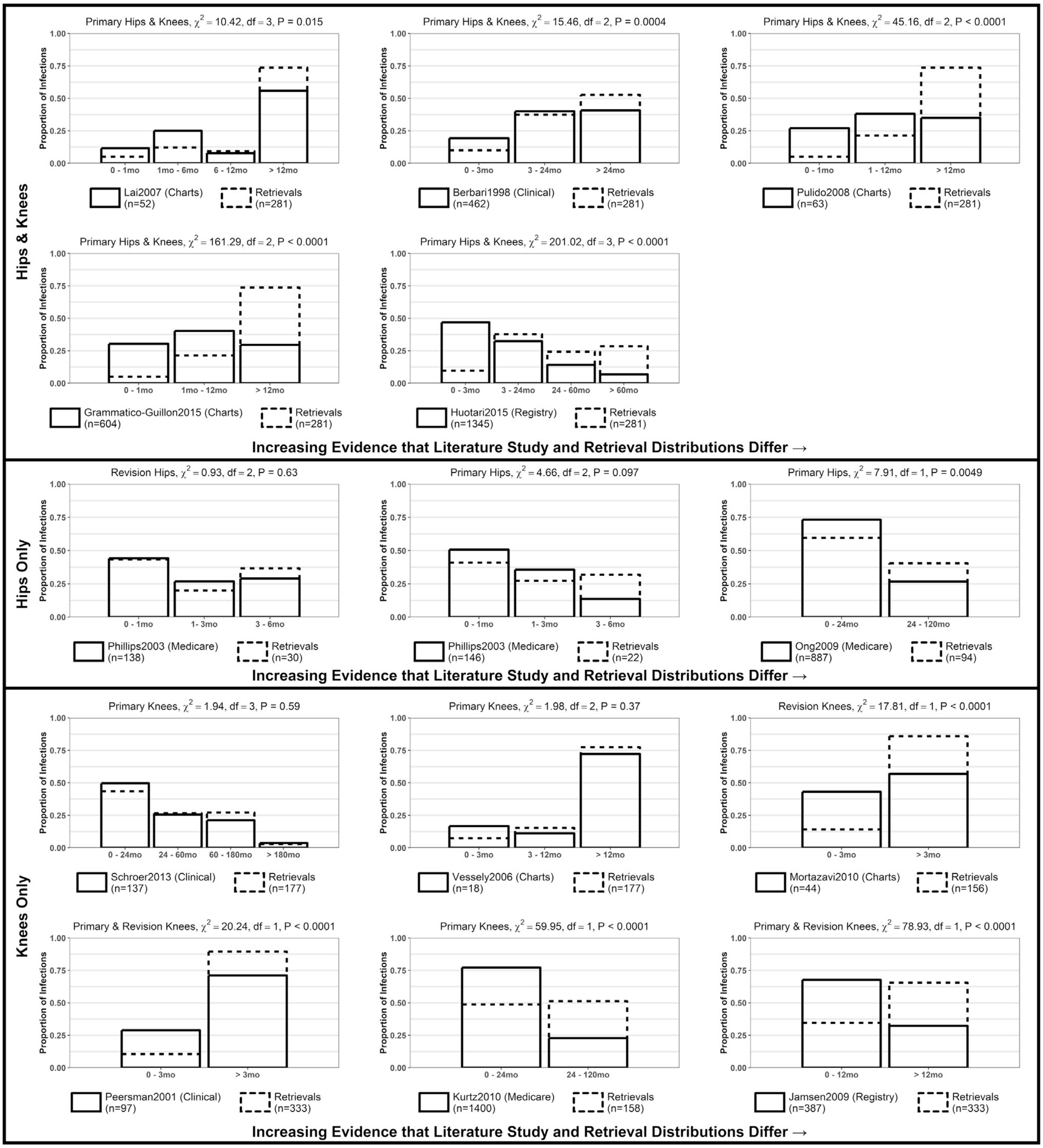

Figure 4. Graphical comparison of the temporal distributions of PJI as published in the clinical literature (solid bars) and those observed through retrieval analysis (dashed bars). Studies in the top 2 rows examine hip and knee arthroplasty together [5,7-10], those in the middle row examine hip replacement [11,12], and those in the last 2 rows examine knee replacement [4,13-17]. Higher values of the χ^2 statistic indicate stronger evidence that retrieval and comparative study distributions differ.

in our 120-month retrieval study ranged from 0.1 to 253.1 months (21.1 years). By enrolling based on revision procedures, this approach inherently loses nobody to follow-up or death, and is unaffected by the rarity of PJI which typically drives the need for large sample sizes in prospective studies with index-based enrollment. Like arthroplasty registries, retrieval analysis can also provide more breadth than is possible in many clinical series [22]. At this time when nationwide joint registries in the United States are nascent and lack historical data, retrieval centers provide a similar, albeit more sparse, mechanism for aggregating explant records from a broad spectrum of institutions.

The retrieval analysis approach to studying PJI is also subject to a number of consequential limitations, stemming largely from its indirect nature. Retrieval studies by definition exclude arthroplasty cases that are never revised, and thus lack a denominator which precludes calculating incidence. The voluntary nature of many

Table 5
Comparison of explant indwelling time distributions with epidemiological characteristics of prosthetic joint infection as published in the clinical literature.

Literature reference									Retrieval data			χ^2	DoF	*P* value
Author, year	Joint(s)	Primary/revision	Region/center	Study population	Enrollment	n	Mean follow-up	Maximum follow-up	n	Mean follow-up	Maximum follow-up			
Lai, 2007	Hip, knee	Primary	Saskatchewan	Revision during the 7-y period, looking back to primary	Endpoint	52	–	204	281	47.6	253.1	10.42	3	**.015**
Berbari, 1998	Hip, knee	Primary	Mayo Clinic	Primary THA and TKA during the 23-y period	Index	462	–	326.4	281	47.6	253.1	15.46	2	**.0004**
Pulido, 2008	Hip, knee	Primary	Rothman	Primary THA and TKA during the 5-y period	Index	63	43	76	281	47.6	253.1	45.16	2	**<.0001**
Grammatico-Guillon, 2015	Hip, knee	Primary	France	Primary THA and TKA during the 5-y period	Index	604	14	40	281	47.6	253.1	161.29	2	**<.0001**
Huotari, 2015	Hip, knee	Primary	Finland	Primary THA and TKA during the 10-y period	Index	1345	–	156	281	47.6	253.1	201.02	3	**<.0001**
Phillips, 2003	Hip	Revision	USA (Medicare)	Hip revision during the 1-y period, looking forward to re-revision	Index	138	–	–	30	2.3	5.1	0.93	2	.63
Phillips, 2003	Hip	Primary	USA (Medicare)	Primary THA during the 1-y period	Index	146	–	–	22	1.9	4.7	4.66	2	.097
Ong, 2009	Hip	Primary	USA (Medicare)	Primary THA during the 10-y period	Index	887	–	120	94	28.8	115.1	7.91	1	**.0049**
Schroer, 2013	Knee	Primary	USA (6 centers)	Revision during the 2-y period, looking back to primary	Endpoint	137	70.8	372	177	49.7	243.9	1.94	3	.59
Vessely, 2006	Knee	Primary	Mayo Clinic	Primary TKA during the 1.5-y period, 14.5-y minimum follow-up	Index	18	188.4	214.8	177	49.7	243.9	1.98	2	.37
Mortazavi, 2010	Knee	Primary	Rothman	Revision during the 7-y period, looking forward to re-revision	Index	44	65	159	158	24.3	198.8	17.81	1	**<.0001**
Kurtz, 2010	Knee	Primary	USA (Medicare)	Primary TKA during the 10-y period	Index	1400	–	–	158	36.3	116.7	59.95	1	**<.0001**
Peersman, 2001	Knee	Primary, revision	HSS	Primary or revision during the 7-y period, looking forward to (re)revision	Index	97	–	156	333	37.8	243.9	20.24	1	**<.0001**
Jamsen, 2009	Knee	Primary, revision	Finland	Primary or revision during the 7-y period, looking forward to (re)revision	Index	387	37.2	103.2	333	37.8	243.9	78.93	1	**<.0001**

DoF, degrees of freedom; THA, total hip arthroplasty; TKA, total knee arthroplasty.
Retrieval data were temporally binned in the same manner as in each paired study, and analyzed using the chi-squared test for independence.
Results printed in bold indicate a statistically significant difference between retrieval and literature distributions at the $\alpha = 0.05$ level.

retrieval programs further complicates the matter, making it difficult to even capture all revision cases. Although the design of the present study minimizes this type of selection bias through contractual agreements that ensure near 100% explant capture from the contributing institutions, there nevertheless exists potential for bias if these institutions are not representative of the broader clinical experience with infection. Such effects have been documented elsewhere [23].

Retrieval studies with 100% capture may still under-represent PJI because not every infection results in an explant. In the related context of registry studies, Labek et al [3] noted that absence of a revision does not imply a satisfactory arthroplasty outcome for the patient. In particular, the polyethylene bearings of implants subjected to conservative treatment measures known as "washouts" or Debridement, Antibiotics, and Implant Retention (DAIR) may or may not be contributed for retrieval analysis [32]. Reported prosthesis salvage rates following "radical debridement" and other conservative measures range from as low as 20% to over 80% [32-36], with successful eradication of PJI depending strongly on early diagnosis, susceptible pathogen(s), and otherwise ideal conditions [32,35-37]. Thus, although the number of conservatively managed infections excluded from this retrieval-based analysis of PJI is unknown, the cases in question likely represent only the most treatable subset of septic arthroplasties.

Accurately distinguishing between early/acute and late/chronic PJI is a challenge common to both clinical and retrieval studies. Timing of the presentation does not reliably indicate pathogen route, as robust biofilm communities are known to coalesce on biomaterial surfaces and give rise to acute infections after long periods of dormancy [32,38]. Recognizing that attributing PJI to a particular vector and route may not always be possible, and also that the clinical treatment plan is largely independent of incubation time, we intentionally made no attempt to distinguish between acute and chronic PJI in this analysis.

A further limitation of the retrieval approach is its dependence on surgeon-reported data, particularly the primary reason for explantation. Several medical bodies have recently formulated complex definitions of PJI to provide clinical guidance in the absence of a complete understanding of the biology and pathophysiology involved [39]; however, the final decision on whether to classify a revision procedure as septic rests with the surgeon. Since the devices included in this study were retrieved by multiple surgeons at each of the 2 participating institutions, some variability is expected in both the reported infection status and the time elapsed between PJI diagnosis and implant retrieval.

Conclusions

Retrieval records paint a clear but incomplete picture of when prosthetic joint infection occurs. In our series of retrievals from 2 institutions, approximately 20% of all revision arthroplasties were performed for the purpose of treating infection, a figure that is higher for re-revisions and also when considering only reoperations performed within the first several years after the index procedure. Implants failed due to infection after a median indwelling time of 18.5 months, while the median failure for all other causes combined occurred after 50.5 months (median difference 23.2 months). Prosthetic hips and knees were explanted for infection after similar indwelling periods of approximately 18 months. The median septic revision of primary joints occurred at 25.7 months, whereas the median septic re-revision was performed after just 12.2 months (median difference 11.2 months). The temporal distribution of PJI cases observed in this retrieval series most closely matches those from studies in which either enrollment was based on the date of revision for infection, or in which follow-up exceeded 10 years. Our data indicate that studies attempting to characterize the temporal aspects of PJI over shorter durations may omit a sizable number of late infections. Although retrieval analysis should not be considered a substitute for high-quality clinical studies designed to characterize the epidemiology of PJI, this approach may provide valuable perspective for physicians and researchers, particularly in the absence of a single, comprehensive joint registry for arthroplasty procedures performed in the United States.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.artd.2019.03.007.

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